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CIRCULAR NO. 167

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AROMATIC FLUORINE COMPOUNDS  
II. 1,2,4,5-TETRAFLUOROBENZENE AND RELATED COMPOUNDS  
III. THE FLUOROMESITYLENES AND DERIVATIVES  
IV. 1,2,3,5-TETRAFLUOROBENZENE  
V. 1,3,5-TRIFLUOROBENZENE

By  
G. C. FINGER AND F. H. REED, ET AL.

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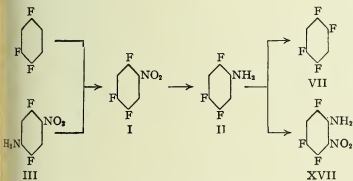
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## Aromatic Fluorine Compounds. II. 1,2,4,5-Tetrafluorobenzene and Related Compounds<sup>1,2</sup>

By G. C. FINGER, F. H. REED, D. M. BURNES, D. M. FORT AND R. R. BLOUGH

The synthesis of a complete series of fluorinated benzenes would reveal the effect of progressive fluorine substitution upon the physical and chemical properties of benzene and benzenoid structures. A tetra- and pentafluorobenzene are needed to complete such a series. In addition, a study of the effect on properties of other substituents in the polyfluorobenzenes would lead to generalizations of theoretical and practical value.

1,2,4,5-Tetrafluorobenzene has been synthesized and the properties of its intermediates were studied in detail. For comparative purposes, a number of chlorofluorobenzenes possessing the 1,2,4,5-structure are reported. Flash points and other physical data accumulated thus far on the fluoro- and chlorofluorobenzenes are summarized. It was discovered that 1,2,4,5-tetrafluorobenzene gave a quinone rather than a nitro derivative under nitration conditions. The anomalous behavior of 2-nitro-3,4,6-trifluoroaniline under diazotization conditions was studied.



The nitration of 1,2,4-trifluorobenzene gave 2,4,5-trifluoronitrobenzene (I) as expected by analogy to the trichloro compound. A Schiemann reaction on 4-nitro-2,5-difluoroaniline (III) produced the same compound, and the position of the nitro group was established by the identity of the acetyl derivatives at II. Reduction gave 2,4,5-trifluoroaniline (II) and a Schiemann conversion

formed 1,2,4,5-tetrafluorobenzene (VII), and a small amount of 2-chloro-1,4,5-trifluorobenzene (VIII) as a by-product.<sup>3</sup>

1,2,4,5-Tetrafluorobenzene resisted photochemical chlorination to a remarkable degree and the only reaction product isolated was a trace of a cyclohexane derivative, C<sub>6</sub>H<sub>2</sub>Cl<sub>4</sub>F<sub>4</sub> (X). In other words, any chlorination that took place did not involve hydrogen substitution, but chlorine addition across the double bonds to form a saturated ring system. This is hardly comparable to the tetrachlorobenzene analog. In contrast, 1,4-difluoro- and 1,2,4-trifluorobenzene halogenated normally, thus making available bromo and chloro derivatives with a 1,2,4,5 structure. The 2-bromo (XI) and 2,5-dibromo (XII) derivatives of 1,4-difluorobenzene were obtained by bromination; likewise, the 2-bromo (IX) derivative of 1,4,5-trifluorobenzene. Sulfuryl chloride<sup>4</sup> chlorination of 1,4-difluorobenzene gave such derivatives as 2-chloro- (XIII), 2,5-dichloro- (XIV) and a small amount of 2,6-dichloro- (XV) and 2,3,5-trichloro-1,4-difluorobenzene (XVI). A trace of hexachlorobenzene was isolated. Apparently the aluminum chloride catalyst caused substitution of fluorine with chlorine in the formation of the hexachloro compound.

The behavior of 1,2,4,5-tetrafluorobenzene with such acids as nitric, sulfuric and their mixtures is unique and in sharp contrast to the chlorine analog. Attempts to form a nitro derivative were unsuccessful. The tetrafluoro compound appeared to be inert to concentrated or fuming nitric and sulfuric acids; with fuming nitric acid in a glass-sealed tube at 125° for four hours, a slight etching of the tube was the only evidence of reaction. There was no reaction with nitric-sulfuric acid mixtures if (1) both components were concentrated, or (2) if one component was fuming and the other concentrated. A nitric-sulfuric acid mixture of fuming reagents reacted with avidity, at times almost uncontrollable even at 5°; 2,5-difluoro-1,4-benzoquinone was identified in the decomposition products. This implies a fluorine displacement-oxidation mechanism involving a pair of fluorine atoms para to each other. Since it was not feasible to obtain a nitro derivative of 1,2,4,5-tetrafluorobenzene by direct nitra-

(3) The formation of chloro by-products in Schiemann reactions is quite common if diazotization is effected in strong hydrochloric acid solutions.

(4) Cutter and Brown, *J. Chem. Ed.*, 21, 443 (1944)

(1) Presented in part before the Organic and Industrial and Engineering Divisions at the 109th (April, 1946) and 116th (September, 1949) Meetings of the American Chemical Society, Atlantic City, N. J. The material in this paper is based on reports submitted to the Office of Scientific Research and Development under Contract OEMar-469 (1942-43), and the Office of Naval Research under Contract N6ori-71; Task XIV (1946-50). The financial assistance of these agencies is gratefully acknowledged.

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tion, the possibility of an alternate synthesis was investigated. The proposed method involved the formation of a 2-nitro derivative of 3,4,6-trifluoroaniline and a subsequent Schiemann reaction to 3-nitro-1,2,4,5-tetrafluorobenzene. Nitration of the acetyl derivative of II gave a 50% yield of 2-nitro-3,4,6-trifluoroaniline (XVII). The Schiemann reaction, however, on the weakly basic nitroamine was unsuccessful, due to failure to obtain an insoluble diazonium fluoroborate and the multiplicity of anomalous reactions extent at the diazo stage.

The perverseness of 2-nitro-3,4,6-trifluoroaniline (XVI) to normal diazo reactions led to a study of the anomalous reaction products of diazotization. Depending upon conditions, evidence was obtained for the formation of two diazo oxides (XIX and XX), nitrodifluorophenol (XXI), iodonitrodifluorophenol (XXII), 2,3-dichloro-1,4,5-trifluorobenzene (XXIII)<sup>6</sup> and dichlorodifluorophenol (XXIV). The formation of these compounds revealed the operation of several mechanisms at the diazo stage such as (1) displacement of fluorine, ortho or para to the diazo group, to form a diazo oxide or phenol, (2) replacement of the nitro group with chlorine in hydrochloric acid solutions, and (3) a combination of these reactions. The ortho or para displacement is supported by the isolation of two apparently isomeric diazo oxides (XIX and XX). Diazotization in hydrochloric acid gave one form (XIX), whereas hydrofluoric gave the other (XX) which, in contrast to the former, could be repeatedly recrystallized from methanol to a definite melting point. Both isomers were light orange in color, exploded on heating or flame ignition, and impact detonation gave a powerful concussion. No structural assignments were made to the diazo oxides or the aforementioned phenols because of the uncertainty of the position of the labilized fluorine atom.

Counterparts of these separate mechanisms in fluorine chemistry are found in Hodgson's<sup>4</sup> diazo oxide from 3-nitro-4-fluoroaniline, and Schiemann's<sup>7</sup> 1-chloro-2-fluoronaphthalene from 1-nitro-2-aminonaphthalene. In other words, the fluorinated nitroamine in question fulfils all the structural conditions necessary to demonstrate the separate findings of Hodgson and Schiemann. As a further test of these findings, 2-nitro-4-chloro-3,6-difluoroaniline has been synthesized and will be reported later. These findings are consistent also with the discussion of Saunders<sup>8</sup> on similar reactions with non-fluorine containing compounds.

Table I is a summary of some of the physical properties of the fluoro- and chlorofluorobenzenes. The boiling point of 1,2,4,5-tetrafluorobenzene is not significantly different than the other fluorobenzenes, but its freezing point is close to that of benzene. The flash point and surface tension

data of the fluoro- and chlorofluorobenzenes are significant in view of the increasing interest in organic fluorine compounds. It is almost inconceivable that the flash point of tetrafluorobenzene is 4°; likewise, the low values for the other fluorinated benzenes. The introduction of one chlorine atom in the fluorinated benzenes elevated the boiling and flash points to the vicinity of chlorobenzene. Progressive fluorine substitution in the benzene molecule caused a progressive decrease in surface tension. This is in contrast to an increase characterized by chlorine or the other halogens. The data also indicate that a decrease in surface tension by fluorine is somewhat compensated for by the introduction of chlorine into the molecule.

TABLE I

PHYSICAL PROPERTIES OF SOME FLUORINATED BENZENES

Compound	F. p., °C.	B. p., °C.	Flash point, °C. (open cup)	Surface tension, dynes/cm., 20°
C <sub>6</sub> H <sub>6</sub>	5.5° <sup>b</sup>	80°	-11° <sup>c</sup>	28.9°
C <sub>6</sub> H <sub>5</sub> F	-41.9° <sup>d</sup>	84.8° <sup>d</sup>	-15	27.71°
C <sub>6</sub> H <sub>4</sub> F <sub>2</sub> -1,4	-13° <sup>d</sup>	88.5° <sup>d</sup>	- 5.5	27.05°
C <sub>6</sub> H <sub>3</sub> F <sub>3</sub> -1,2,4	-35° <sup>d</sup>	88° <sup>d</sup>	- 5	26.2
C <sub>6</sub> H <sub>2</sub> F <sub>4</sub> -1,2,4,5	4	88	4	24.9
C <sub>6</sub> H <sub>3</sub> Cl <sup>b</sup>	-45	132	32°	33.2
C <sub>6</sub> H <sub>4</sub> (F)(Cl)-1,4	-27° <sup>b</sup>	130° <sup>b</sup>	32	31.3
C <sub>6</sub> H <sub>3</sub> (F) <sub>2</sub> (Cl)-1,4,2	-24.6	127	31	29.9

<sup>a</sup> Melting point. <sup>b</sup> Data taken from Lange, "Handbook of Chemistry," Handbook Publishers, Inc., Sandusky, Ohio. <sup>c</sup> Closed cup. <sup>d</sup> Timmermans and Hennaat-Roland, *J. chim. phys.*, 32, 501 (1935). <sup>e</sup> Desreux, *Bull. soc. chim. Belg.*, 44, 249 (1935). <sup>f</sup> Schiemann and Pillarsky, *Ber.*, 62, 3035 (1929). <sup>g</sup> Schiemann, *J. prakt. Chem.*, 40, 97 (1934).

Experimental<sup>9-11</sup>

**2,4,5-Trifluoronitrobenzene (I).**—To a mixture of 200 g. of concd. nitric and 736 g. of concd. sulfuric acids, 264 g. of 1,2,4-trifluorobenzene<sup>12</sup> was added with stirring. The reaction temperature was maintained at 20° and the time was three hours. Steam distillation of the crude material gave a yield of 307 g. or 87% of practically pure nitro compound. Pure 2,4,5-trifluoronitrobenzene has a mild nitrobenzene odor, but is somewhat lachrymatory, f. p. ca. -11°, b. p. 93.5° (20 mm.) or 192° (atm.), *n*<sub>D</sub><sup>20</sup> 1.49384.

*Anal.* Calcd. for C<sub>6</sub>H<sub>3</sub>F<sub>3</sub>NO<sub>2</sub>: C, 40.69; H, 1.14; N, 7.91. Found: C, 40.73; H, 1.15; N, 8.19.

The same nitro compound was obtained by a Schiemann reaction on 4-nitro-2,5-difluoroaniline (III), thus proving its structure.

**2,4,5-Trifluoroaniline (II).**—This compound was obtained in a 90% yield by an iron reduction of I. Steam distillation gave a colorless oil which solidified to a white solid on cooling. Recrystallization from high boiling petroleum ether gave white needles, m. p. 58.5-60°.

*Anal.* Calcd. for C<sub>6</sub>H<sub>3</sub>F<sub>3</sub>N: C, 48.99; H, 2.74; N, 9.52. Found: C, 48.90; H, 2.95; N, 9.45.

The acetyl derivative was recrystallized from aqueous ethanol as white microcrystals, m. p. 129-130°. A mixed melting point of the acetyl derivatives of the amines derived from the two routes proved them to be identical.

*Anal.* Calcd. for C<sub>8</sub>H<sub>4</sub>F<sub>3</sub>NO: C, 50.80; H, 3.20; N, 7.41. Found: C, 50.80; H, 3.28; N, 7.46.

(9) Analyses by H. S. Clark, microanalyst for the Survey.

(10) Melting and boiling points are uncorrected. Freezing point were determined with a toluene thermometer.

(11) The assistance of Messrs. J. L. Finnerty, E. W. Maynert, R. F. Oesterling, H. G. Schneider, A. M. Weiner and O. F. Williams is grate fully acknowledged.

(12) Schiemann, *J. prakt. Chem.*, 140, 97 (1934).

(5) A Sandmeyer reaction gave a 40% yield of this compound. Frequent use of this reaction has been made in this Laboratory to convert fluorinated ortho nitroamines to the corresponding fluorinated ortho dichloro derivatives.

(6) Hodgson and Nixon, *J. Chem. Soc.*, 2272 (1931).

(7) Schiemann and Ley, *Ber.*, 69, 960 (1936).

(8) K. H. Saunders, "The Aromatic Diazo-Compounds and Their Technical Applications," Edward Arnold & Co., London, 2nd ed., 1949.



**4-Nitro-2,5-difluoroaniline (III).**—To a solution of 116 g. of 2,5-difluoroacetanilide<sup>13</sup> in 500 cc. of concd. sulfuric acid and 50 cc. of acetic acid, a mixture of 57.5 cc. of concd. nitric and 75 cc. of concd. sulfuric acids was added in 75 minutes, and the temperature maintained below 10°. The crude nitroacetylamino compound, obtained in a quantitative yield, was hydrolyzed in 150 cc. of concd. sulfuric acid by heating for ten minutes on a steam-bath. A yield of 105 g. or 89% of crude nitroamine was obtained. Recrystallization from ethanol gave pure 4-nitro-2,5-difluoroaniline as golden needles, m. p. 153–153.5°. The mother liquor was reserved for the isolation of an isomer (IV).

*Anal.* Calcd. for  $C_6H_3F_2N_2O_2$ : C, 41.40; H, 2.32; N, 16.10. Found: C, 41.63; H, 2.14; N, 16.31.

Recrystallization of the acetyl derivative from ethanol gave cream-colored crystals, m. p. 189–189.5°.

*Anal.* Calcd. for  $C_8H_5F_2N_2O_3$ : N, 12.96. Found: N, 12.77.

**6-Nitro-2,5-difluoroaniline (IV).**—This compound, an isomer of III, was isolated in a very small amount from the mother liquor obtained in the purification of III. A combination of sublimation and recrystallization from ethanol gave pure 2-nitro-3,6-difluoroaniline as orange needles, m. p. 80–80.5°.

*Anal.* Calcd. for  $C_6H_3F_2N_2O_2$ : C, 41.40; H, 2.32; N, 16.10. Found: C, 41.57; H, 2.38; N, 16.10.

Sublimation gave the acetyl compound as a white solid, m. p. 160–161°.

*Anal.* Calcd. for  $C_8H_5F_2N_2O_3$ : N, 12.96. Found: N, 12.90.

The structure of this nitroamine was proven by reduction to the diamine (V) and the subsequent formation of a quinazoline.

**3,6-Difluoro-1,2-phenylenediamine (V).**—The diamine was prepared from IV by the usual stannous chloride reduction. It was quite soluble in water and was extracted with ether. Vacuum sublimation gave the pure diamine as fine white needles, m. p. 80.8–81.1°.

*Anal.* Calcd. for  $C_6H_6F_2N_2$ : C, 50.00; H, 4.20; N, 19.45. Found: C, 50.15; H, 4.22; N, 19.60.

The 2,3-diphenyl-5,8-difluoroquinazoline derivative was prepared by condensation of the diamine with benzil. Recrystallization from ethanol gave fine white crystals, m. p. 191–191.5°.

*Anal.* Calcd. for  $C_{20}H_{14}F_2N_4$ : C, 75.45; H, 3.80; N, 8.80. Found: C, 75.55; H, 3.80; N, 8.75.

**2,5-Difluoro-1,4-phenylenediamine (VI).**—This diamine was prepared from III by the same procedure described for V. Vacuum sublimation gave white crystals, m. p. 129–129.6°.

*Anal.* Calcd. for  $C_6H_6F_2N_2$ : C, 50.00; H, 4.20; N, 19.45. Found: C, 49.91; H, 4.28; N, 19.52.

The diacetate derivative upon recrystallization from acetic acid gave white microneedles, m. p. 304.5–305.5°.

*Anal.* Calcd. for  $C_{10}H_{10}F_2N_4O_4$ : N, 12.28. Found: N, 12.00.

**1,2,4,5-Tetrafluorobenzene (VII).**—A well-stirred mixture of 294 g. of 2,4,5-trifluoroaniline and 1100 cc. of commercial hydrochloric acid (18° Bé.) was heated until complete solution was obtained and then rapidly cooled to –5° to precipitate the amine hydrochloride. The resulting mixture was diazotized by the submerged addition of a solution of 140 g. of sodium nitrite in 210 cc. of water, and the temperature not allowed to go above 0°. After completion of the diazotization, a solution of 660 g. of sodium fluoroborate in 940 cc. of water was added rapidly. The heavy slurry was stirred for 30 minutes, cooled to –15°, filtered and the light yellow fluoroborate salt was dried. The yield of dry salt was over theory. After thermal decomposition by the usual procedure,<sup>14</sup> the crude reaction product was made alkaline with sodium carbonate solution and steam distilled. Distillation through a packed column gave a fraction boiling at 89–90.5°, yield 113–137 g. or 38–46% based on the amine. Pure 1,2,4,5-tetrafluorobenzene has a faint sweet odor. *p.* ca. 4°, *b.* p. 88°, *d*<sub>4</sub><sup>20</sup>, 1.4256, *n*<sub>D</sub><sup>20</sup> 1.4074.

*Anal.* Calcd. for  $C_6H_2F_4$ : C, 48.01; H, 1.34. Found: C, 47.93; H, 1.42.

**2-Chloro-1,4,5-trifluorobenzene (VIII).**—This compound was obtained in a 60% yield from 2,4,5-trifluoroaniline by a Sandmeyer reaction or as a by-product from the tetrafluorobenzene synthesis, *f. p.* ca. –24.5°, *b. p.* 124–125°.

*Anal.* Calcd. for  $C_6H_2ClF_3$ : C, 43.27; H, 1.21. Found: C, 43.65; H, 1.19.

**2-Bromo-1,4,5-trifluorobenzene (IX).**—Bromination of 1,2,4-trifluorobenzene with iron as a catalyst gave a 76% yield of 2-bromo-1,4,5-trifluorobenzene, *f. p.* ca. –19°, *b. p.* 144°, *d*<sub>4</sub><sup>20</sup>, 1.8022, *n*<sub>D</sub><sup>20</sup>, 1.4862, *γ*<sub>D</sub><sup>20</sup> 25.6 dynes/cm.

*Anal.* Calcd. for  $C_6H_2BrF_3$ : C, 34.15; H, 0.95; Br, 37.88. Found: C, 34.07; H, 0.95; Br, 37.87.

**1,2,3,4,5,6-Hexachloro-1,2,4,5-tetrafluorocyclohexane (X).**—A small amount of high-boiling material was the only evidence of the effect of exhaustive chlorination on 1,2,4,5-tetrafluorobenzene. A combination of vacuum distillation, recrystallization from ethanol, and sublimation gave a very small amount of white crystals, m. p. 79–80°, as the only isolable product. According to the analytical data, the white solid is a hexachlorotetrafluorocyclohexane.

*Anal.* Calcd. for  $C_6H_2Cl_6F_4$ : C, 19.85; H, 0.55; Cl, 58.64. Found: C, 19.84; H, 0.70; Cl, 58.38.

**Halogenation of *p*-Difluorobenzene.**—Bromination of *p*-difluorobenzene with bromine in the presence of iron gave the mono and dibromo derivatives with the latter being in largest amount. Both derivatives were removed from the reaction mixture by steam distillation, and then separated by vacuum distillation.

**2-Bromo-1,4-difluorobenzene (XI).**—This compound has a mild bromobenzene odor, *f. p.* ca. –31.5°, *b. p.* 58–58.5° (20 mm.), *n*<sub>D</sub><sup>20</sup> 1.5086.

*Anal.* Calcd. for  $C_6H_4BrF_2$ : C, 37.34; H, 1.56; Br, 41.41. Found: C, 37.43; H, 1.62; Br, 41.06.

**2,5-Dibromo-1,4-difluorobenzene (XII).**—This is a crystalline solid, sublimes slowly on standing, and is recrystallizable from ethanol, m. p. 64.5–65.5°, *b. p.* 96° (20 mm.).

*Anal.* Calcd. for  $C_6H_2Br_2F_2$ : C, 26.50; H, 0.74; Br, 58.78; F, 13.98. Found: C, 26.61; H, 0.74; Br, 58.91; F, 13.48.

Chlorination of *p*-difluorobenzene was effected by the sulfur chloride-sulfur monochloride method with aluminum chloride as a catalyst.<sup>4</sup> A moderate excess of reagent gave the monochloro derivative, but this in turn chlorinated readily to the 2,5-dichloro compound. Chlorination beyond the dichloro stage was much slower. A large excess of chlorinating agent formed a complex mixture which gave a 60–70% yield of the 2,5-dichloro-1,4-difluorobenzene, a small amount of what may be 2,6-dichloro-1,4-difluorobenzene, 15–20% of 2,3,5-trichloro-1,4-difluorobenzene, and a trace of hexachlorobenzene. Separation of the components was by steam and vacuum distillations, and recrystallizations.

**2-Chloro-1,4-difluorobenzene (XIII).**—In addition to the direct chlorination, this compound was obtained as a by-product from the synthesis of 1,2,4-trifluorobenzene or by a Sandmeyer reaction on 2,5-difluoroaniline in a 60% yield, *f. p.* ca. 24.6°, *b. p.* 128°, *d*<sub>4</sub><sup>20</sup>, 1.3561, *n*<sub>D</sub><sup>20</sup> 1.4772.

*Anal.* Calcd. for  $C_6H_4ClF_2$ : C, 48.51; H, 2.04; Cl, 23.87. Found: C, 48.46; H, 2.07; Cl, 23.86.

**2,5-Dichloro-1,4-difluorobenzene (XIV).**—The reaction product (177 g.) from exhaustive chlorination was divided arbitrarily into three volatile fractions, and a small non-volatile fraction by steam distillation. The order of volatile fractions was (1) a condensate (87 g.) which solidified on cooling, (2) an oil (80 g.) which remained a liquid at room temperature, and (3) a white solid. The residue (1.2 g.) and the last fraction (2.6 g.) was essentially hexachlorobenzene.

The first volatile fraction was almost pure 2,5-dichloro-1,4-difluorobenzene. As a result of processing the second fraction, an additional 25 g. of this dichloro derivative was accumulated from this source. It was identified by a mixed melting point with a known sample obtained from 4-nitro-2,5-difluoroaniline (III).

The synthesis of this compound from III was accomplished in one step by the simultaneous replacement of a nitro group with chlorine while a cuprous chloride Sandmeyer reaction was operating on the amino group. Fre-

(13) Swarts, *Bull. classe sci., Acad. roy. Belg.*, 241 (1913); 186 (1914).

(14) Finger and Reed, *This Journal*, 66, 1972 (1944).

quent use of this reaction has been made with ortho-nitroamines to form dichlorides. Ten grams of III was diazotized as the amine hydrochloride at 40–45°, and then poured into a cuprous chloride solution. The crude reaction product was a mixture of the dichloro and chloronitro derivatives; a vacuum sublimation gave 3.2 g. of practically pure dichloro compound as the most volatile component.

Recrystallization from ethanol gave 2,5-dichloro-1,4-difluorobenzene as white crystals, m. p. 48–49°, b. p. 64° (20 mm.) or 164° (atm.).

*Anal.* Calcd. for  $C_6H_2Cl_2F_2$ : C, 39.38; H, 1.10; Cl, 38.75. Found: C, 39.44; H, 1.08; Cl, 38.78.

**2,6-Dichloro-1,4-difluorobenzene (XV).**—The second volatile fraction described under XIV was processed by fractional distillation into various cuts. In general, material boiling above 180° was reserved for the isolation of the trichloro derivative. Fractions boiling up to 180° were processed by repeated distillations and freezing of fractions to eliminate the 2,5-dichloro compound. The end result was several grams of oil, f. p. 3.5 to –10°, b. p. 65–66° (20 mm.),  $n_D^{20}$  1.50750.

*Anal.* Calcd. for  $C_6H_2Cl_2F_2$ : C, 39.38; H, 1.10; Cl, 38.75. Found: C, 39.36; H, 1.17; Cl, 38.63.

There is little doubt that this material essentially is 2,6-dichloro-1,4-difluorobenzene. A synthetic sample prepared recently by a Sandmeyer reaction on 3-chloro-2,5-difluoroaniline<sup>15</sup> had practically the same properties, f. p. ca. –1.5 to 2.5°, b. p. 165°,  $n_D^{20}$  1.50405.

*Anal.* Calcd. for  $C_6H_2Cl_2F_2$ : C, 39.38; H, 1.10. Found: C, 39.40; H, 1.06.

**2,3,5-Trichloro-1,4-difluorobenzene (XVI).**—The fraction boiling above 180° as indicated under XV and the higher cuts obtained from the isolation of the 2,6-dichloro compound were combined. This composite sample was redistilled to give about 30 g. of a middle fraction, b. p. 180–207°. Repeated fractional distillation and freezing of the fractions removed the hexachlorobenzene as a solid and with the elimination of the lower boiling fractions, an enriched trichloro fraction, b. p. 190–205°, was obtained. Redistillation of the enriched fraction gave about 25 g. of fairly pure material. Approximately 20 g. of pure 2,3,5-trichloro-1,4-difluorobenzene was finally isolated, f. p. ca. –11.5 to –12°, b. p. 94–95° (20 mm.) or 200° (atm.),  $n_D^{20}$  1.5340.

*Anal.* Calcd. for  $C_6HCl_3F_2$ : C, 33.14; H, 0.46; Cl, 48.92. Found: C, 33.43; H, 0.56; Cl, 48.94.

**Quinone Formation.**—All attempts to prepare a nitro derivative of 1,2,4,5-tetrafluorobenzene (VII) by nitration failed. The unusual stability of this compound to nitric-sulfuric acid mixtures was discussed previously, and for the sake of brevity the isolation of the quinone intermediate will be described.

To a well-stirred mixture of 30 g. of 1,2,4,5-tetrafluorobenzene (VII) and 13.9 g. of fuming sulfuric acid (30%  $SO_3$ ), 20 cc. of fuming nitric acid (1.49–1.5) was added dropwise and the reaction temperature maintained at 25–30°. The mixture became orange-red in color, a yellow solid formed, and a slow evolution of hydrogen fluoride was observed. After pouring the reaction mixture over ice, the yellow solid was removed by filtration, washed with water, dried, yield 8–10 g. It was purified by recrystallization from carbon disulfide or by sublimation, m. p. 171.5–172°. A mixed melting point with a known sample of 2,5-difluoro-1,4-benzoquinone<sup>16</sup> proved its identity.

**2-Nitro-3,4,6-trifluoroaniline (XVII).**—To a solution of 500 g. of 2,4,5-trifluoroacetanilide in 445 cc. of glacial acetic and 1550 cc. of concentrated sulfuric acids, a mixture of 200 cc. of fuming nitric acid (1.49–1.5) in 55 cc. of acetic and 195 cc. of concd. sulfuric acids was added slowly, and the temperature maintained at 20°. Stirring was continued for 30 minutes after addition, and some hydrogen fluoride evolution was observed during the nitration. After removal of the precipitate by filtration, the aqueous filtrate was extracted with ether for maximum recovery. The entire crude product (425 g.) was hydrolyzed with 300 cc. of concd. hydrochloric acid in 2700 cc. of water by refluxing for two hours. Steam distillation gave 267 g. (53%) of nitroamine, sufficiently pure for subsequent reactions. Vacuum

sublimation gave pure 2-nitro-3,4,6-trifluoroaniline as a bright orange solid, m. p. 57.3–57.8°.

*Anal.* Calcd. for  $C_6H_3F_3N_2O_2$ : C, 37.52; H, 1.57; N, 14.59. Found: C, 37.78; H, 1.44; N, 14.51.

The acetyl derivative was purified by recrystallization from carbon tetrachloride and by vacuum sublimation, m. p. 124.5–124.8°.

*Anal.* Calcd. for  $C_8H_5F_3N_2O_2$ : N, 11.97. Found: N, 11.81.

**3,4,6-Trifluoro-1,2-phenylenediamine (XVIII).**—This diamine was prepared in an 82% yield by an iron reduction from the preceding nitroamine. Vacuum sublimation gave white needles, m. p. 74.6–75.2°.

*Anal.* Calcd. for  $C_6H_3F_3N_2$ : C, 44.45; H, 3.11; N, 17.28. Found: C, 44.65; H, 2.95; N, 17.06.

The quinoxaline derivative was prepared by the usual reaction with benzil in a 75% yield, and purified by passage through an aluminum oxide chromatograph in addition to recrystallization from ethanol. The pure 2,3-diphenyl-5,6,8-trifluoroquinoxaline was obtained as white needles, m. p. 169.5–170°.

*Anal.* Calcd. for  $C_{18}H_{11}F_3N_2$ : N, 8.33. Found: N, 8.26.

**Diazotization of 2-Nitro-3,4,6-trifluoroaniline.**—A variety of products was obtained by diazotization of 2-nitro-3,4,6-trifluoroaniline, depending upon the acid media and reagents used. Since a fluorine atom in the 4- or 6-position could be replaced, the structures of the diazo oxides or the phenolic compounds were not determined. In general, the phenolic compounds were converted to a benzoyl derivative in order to obtain a satisfactory analysis.

**Diazo Oxides (XIX and XX).**—Two apparently different diazo oxides of the same chemical composition were obtained, one was derived from diazotization in hydrochloric acid (XIX) and the other from hydrofluoric acid (XX). It is conceivable that one represents a fluorine replacement at the 4-position and the other at the 6-position.

The hydrochloric acid diazotization involved 5 g. of the nitroamine, 10 cc. of concd. hydrochloric acid and 3 g. of sodium nitrite in 5 cc. of water. The bright orange-colored precipitate was removed by filtration; the filtrate gave no precipitate with sodium fluoride solution, thus negating a Schiemann reaction. After drying the precipitate, it melted near 80°, and burned explosively in a flame; one recrystallization from methanol gave orange colored crystals (XIX), which darkened upon heating but not melting up to 350°, and exploding violently on impact.

*Anal.* Calcd. for  $C_6HF_3N_3O_2$ : C, 35.83; H, 0.50; N, 20.90. Found: C, 35.95; H, 0.55; N, 20.71.

The hydrofluoric acid diazotization was similar to the above except 48% aqueous acid was used, and the reaction was performed in a rubber beaker. Due to the presence of insoluble salts, the dried orange precipitate was extracted with ether in a Soxhlet, and evaporation of the ether extract gave a crude red product. Repeated recrystallization from methanol gave a bright orange powder (XX), m. p. 119.3–120° (dec.), with the same characteristics as the preceding compound.

*Anal.* Calcd. for  $C_6HF_2N_3O_2$ : C, 35.83; H, 0.50; N, 20.90. Found: C, 35.75; H, 0.43; N, 20.80.

**Nitrodifluorophenol (XXI).**—Diazotization of the nitroamine (25 g.) in concd. sulfuric acid and application of the hypophosphorous deamination method gave a small amount of the solid from chloroform and vacuum sublimation gave yellow crystals, m. p. 105–105.5°. A benzoyl derivative was prepared by the Schotten-Baumann reaction; recrystallization from ethanol gave white plates, m. p. 88–89°.

*Anal.* Calcd. for  $C_6H_2F_2NO_2$ : C, 55.92; H, 2.53; N, 5.02. Found: C, 56.31; H, 2.27; N, 5.01.

**Iodonitrodifluorophenol (XXII).**—This compound was obtained in very small amount by diazotization of the nitroamine in sulfuric acid followed by treatment with potassium iodide. A Schotten-Baumann reaction gave the benzoyl derivative, recrystallizable from ethanol to cream-colored needles, m. p. 135–136°.

*Anal.* Calcd. for  $C_6H_2F_2INO_2$ : C, 38.54; H, 1.49; N, 3.46. Found: C, 39.14; H, 1.46; N, 3.12.

**2,3-Dichloro-1,4,5-trifluorobenzene (XXIII).**—A suspension of 25 g. of powdered nitroamine in 50 cc. of concd. hy-

(15) Finger, Reed and Finnerty, unpublished results.

(16) Finger, Finnerty and Schneider, Abstracts of 116th A. C. S. Meeting, September, 1949, Atlantic City, N. J., p. 17K.

dichloric acid was diazotized at  $-5^{\circ}$  with the slow addition of 15 g. of powdered sodium nitrite. The resulting mixture was poured into a solution of 25 g. of cuprous chloride in 100 cc. of concd. hydrochloric acid. Steam distillation removed the dichloro compound as an oil, and the aqueous layer was reserved for the isolation of the dichlorodifluorophenol. The crude product, yield 10.6 g. or 40%, on distillation gave pure 2,3-dichloro-1,4,5-trifluorobenzene, f.p. ca.  $-3$  to  $-4^{\circ}$ , b.p.  $153^{\circ}$ ,  $n_D^{20}$  1.48866.

Anal. Calcd. for  $C_6HCl_2F_3$ : C, 35.85; H, 0.50; Cl, 35.28. Found: C, 35.92; H, 0.57; Cl, 34.90.

The cloudy supernatant liquid from steam distillation on chilling gave a few drops of oil, with a phenolic odor (XXIV), which was converted to a benzoyl derivative. Recrystallization from ethanol and a subsequent vacuum sublimation gave the derivative as a white powder, m.p.  $84.5-85^{\circ}$ .

Anal. Calcd. for  $C_{12}H_5Cl_2F_3O_2$ : C, 51.51; H, 2.00; Cl, 23.40. Found: C, 51.48; H, 1.74; Cl, 23.40.

**Flash Points and Surface Tension.**—The flash points were determined by the Pensky-Martens closed tester.<sup>17</sup>

Surface tension was determined by H. S. Clark using the micro-capillary tube method.<sup>18</sup>

(17) "1949 Book of A. S. T. M. Standards," A. S. T. M. Designation: D93-46, American Society for Testing Materials, Philadelphia, Pa.

(18) Natelson and Pearl, *This Journal*, **87**, 1520 (1935).

## Summary

The synthesis and properties of 1,2,4,5-tetrafluorobenzene and a group of bromofluoro and chlorofluorobenzenes with a predominating 1,2,4,5-structure are described. Flash point and surface tension data for the fluorinated benzenes and the influence of chlorine substitution upon these values were studied.

Under nitration conditions, 1,2,4,5-tetrafluorobenzene will not form a nitro derivative, but will undergo a preferential 1,4-fluorine displacement-oxidation mechanism to give 2,5-difluoro-1,4-benzoquinone.

Diazotization reactions on 2-nitro-3,4,6-trifluoroaniline reveal that the nitro group or a fluorine atom in the 4- or 6-position may become labilized, under certain conditions, and undergo replacement.

URBANA, ILLINOIS

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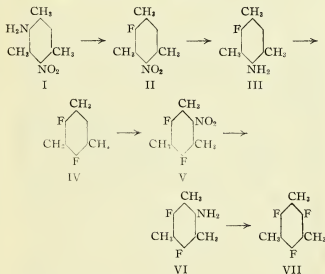
## Aromatic Fluorine Compounds. III. The Fluoromesitylenes and Derivatives<sup>1</sup>

BY G. C. FINGER, F. H. REED, E. W. MAYNERT AND A. M. WEINER

As part of a study in this Laboratory on aromatic fluorides, 2,4-difluoro- and 2,4,6-trifluoromesitylene, and various fluorinated mesitylene derivatives were synthesized. Monofluoromesitylene was synthesized by Töhl<sup>2</sup> as early as 1892. Of special note is the synthesis of 2,4,6-trichloro-1,3,5-trifluorobenzene.

Dinitromesitylene was prepared in quantitative yields by the nitration of mesitylene in anhydrous hydrofluoric acid by the Fredenhagen process.<sup>3</sup> This method has much in its favor over the Fittig<sup>4</sup> red fuming nitric acid procedure. A sodium polysulfide reduction of the dinitro compound gave nitromesidine (I), and by means of a diazotization-Schiemann transformation 2-fluoro-4-nitromesitylene (II) was obtained. An iron reduction of II gave fluoromesidine (III), and a Schiemann reaction on the amine gave a 80-90% yield of 2,4-difluoromesitylene (IV).

A 90% yield of 2,4-difluoro-6-nitromesitylene (V) was obtained by the above hydrogen fluoride nitration process on IV. Difluoromesidine (VI), prepared by an iron reduction of V, was converted in an 86% yield to 2,4,6-trifluoromesitylene (VII) by a Schiemann reaction. The yields of difluoromesitylene and trifluoromesitylene from their



respective amines are among the highest recorded for a Schiemann reaction.<sup>5</sup>

The chlorination of trifluoromesitylene readily gave a "hexachloro" derivative, probably 2,4,6-tris-(dichloromethyl)-1,3,5-trifluorobenzene, and this was converted slowly at a higher temperature to 2,4,6-tris-(trichloromethyl)-1,3,5-trifluorobenzene. The latter was complicated by chlorinolysis which gave rise to 2,4,6-trichloro-1,3,5-trifluorobenzene and carbon tetrachloride. Similar results had been reported for mesitylene and the chloromesitylenes.<sup>6,7</sup> Trifluoromesitylene with its chlorinated derivatives, and trichlorotrifluoroben-

(1) Presented in part before the Organic Division at the 109th meeting of the American Chemical Society, Atlantic City, N. J., April 1946. The material in this paper is based, primarily, on reports submitted to the Office of Scientific Research and Development under contract OEMsr-469(1942-43) and on data obtained after the expiration of the contract. Published with the permission of the Chief of the Illinois State Geological Survey.

(2) Töhl, *Ber.*, **25**, 1525 (1892).  
(3) (a) Fredenhagen, German Patent 529,538 (Aug. 2, 1930); *C. A.*, **5**, 5175 (1931). (b) "New Methods of Preparative Organic Chemistry," Interscience Publishers, Inc., New York, N. Y., 1948, pp. 340-3.

(4) Fittig, *Ann.*, **141**, 133 (1867).

(5) "Organic Reactions," John Wiley and Sons, Inc., New York, N. Y., 1949, Vol. V, Ch. 4, pp. 217-222.

(6) I. G. Farbenind., A.-G., French Patent 798,727 (May 25, 1936); *C. A.*, **30**, 7121 (1936).

(7) McBee and Leech, *Ind. Eng. Chem.*, **39**, 393 (1947).

zene possess the characteristic structure of symmetrical trifluorobenzene.

Mesitylene with trifluoroacetic anhydride undergoes the Friedel-Crafts acylation reaction to form the trifluoroacetyl derivative. Various aceto derivatives of difluoromesitylene were prepared and, presumably, the same reactions could be applied to monofluoromesitylene. Sodium hypobromite converted the acetodifluoromesitylene to the tribromoaceto derivative which was degraded to *iso*-difluoro- $\beta$ -isodurylic acid. Attempts to produce the same acid by the hydrolysis of 2-cyano-4,6-difluoromesitylene failed because of the stability of the amide intermediate.

The boiling points of mono-, di- and trifluoromesitylene, 167,<sup>7</sup> 169 and 169<sup>7</sup>, respectively, are slightly higher than mesitylene, b. p. 164°. The trifluoro compound is a solid, m. p. 68° in contrast to mesitylene and the other fluoromesitylenes which are liquids; it is quite volatile, sublimes slowly on standing, and exhibits thixotropic properties.

### Experimental<sup>8,9</sup>

**Nitrations in Anhydrous Hydrogen Fluoride.**—The reaction vessel for nitrations in liquid anhydrous hydrofluoric acid was either an iron retort or a copper beaker. An anchor-shaped stirrer was used to ensure efficient agitation at all times. A thermometer well extended down to the center of the reaction vessel close to the stirrer shaft. The reaction temperature was controlled by an external Dry Ice-acetone cooling bath.

**A. Dinitromesitylene.**—To a cooled, well-stirred mixture of 2 kg. (100 moles) of liquid anhydrous hydrofluoric acid and 500 g. (4.17 moles) of mesitylene, 708 g. (8.34 moles) of powdered sodium nitrate was added at such a rate that the reaction temperature was held below 5°. Stirring was continued for 15–30 minutes. The dinitromesitylene precipitated as a yellow solid, and the final reaction mixture was a heavy sludge.

After pouring the reaction mixture over 5 kg. of crushed ice with vigorous stirring, the dinitromesitylene was removed and washed with water on a Buchner funnel, and dried. Yield was 805–840 g. or 94–98%, m. p. 84–85° (Fittig reported 86°). This product was sufficiently pure for the sodium polysulfide reduction to nitromesitylene.

**B. 2,4-Difluoro-6-nitromesitylene (V).**—Difluoromesitylene (0.77 mole) was nitrated in liquid anhydrous hydrofluoric acid (50 moles) by the addition of sodium nitrite (0.8 mole) according to the above procedure except that external cooling was not necessary. Yield of crude nitro compound was 90–92%, m. p. 53°.

*Anal.* Calcd. for  $C_8H_5O_2NF_2$ : C, 53.73; H, 4.51; N, 6.96. Found: C, 53.93; H, 4.49; N, 7.10.

A "mixed" acid nitration with concd. nitric and sulfuric acids gave the same nitro compound but in a slightly lower yield. Steam distillation gave a fairly pure product.

**2-Fluoro-4-nitromesitylene (II).**—A mixture of 400 g. of crude, powdered nitromesitylene<sup>10</sup> and 1150 cc. of concd. hydrochloric acid was heated to form the amine hydrochloride, and then chilled rapidly to 0°. A solution of 190 g. of sodium nitrite in 350 cc. of water was added slowly while the reaction temperature was maintained at –5 to 0°. The clear diazonium chloride solution, after skimming off any tar-like material floating on the surface, was cooled to –10°, and a solution of 360 g. of sodium fluoborate in 430 cc. of water was added to form the insoluble diazonium fluoborate. In general, a yield of 95% was obtained.

The fluoborate salt was decomposed by careful heating in a large round-bottom flask equipped with a large bore, air re-

flux condenser, and allowing the exit gases to escape in a hood. After gas evolution had ceased, an ether extraction removed the crude product from the black, solid residue. The ether extract, after the usual water and 5% sodium hydroxide solution washings, drying and evaporation, gave a crude yield ranging from 210–270 g. or 63–67% based on the mesidine. Vacuum distillation gave pure 2-fluoro-4-nitromesitylene as a pale yellow, crystalline solid, m. p. 43–44°, b. p. 97–99° (10 mm.).

*Anal.* Calcd. for  $C_8H_5O_2NF$ : C, 59.00; H, 5.50; N, 7.64. Found: C, 58.73; H, 5.52; N, 7.63.

**2-Fluoro-4-aminomesitylene (III).**—This amine was prepared from the preceding nitro compound by the usual iron reduction<sup>11</sup> in an 88% yield. Steam distillation gave a product sufficiently pure for the subsequent reactions. Recrystallization from low boiling petroleum ether gave pure 2-fluoro-4-aminomesitylene as a white solid, m. p. 38.5–39.5°.

*Anal.* Calcd. for  $C_8H_9NF$ : C, 70.56; H, 7.90; N, 9.15. Found: C, 70.68; H, 7.75; N, 9.21.

Recrystallization of the acetyl derivative from aqueous ethanol gave white needles, m. p. 181–182°.

*Anal.* Calcd. for  $C_{10}H_{11}ONF$ : N, 7.18. Found: N, 7.22.

**2,4-Difluoromesitylene (IV).**—This compound was prepared from 2-fluoro-4-aminomesitylene (III) by the usual procedure.<sup>11</sup> The yield of diazonium fluoborate salt was 90–100%, and the crude yield of difluoromesitylene was 80–90% based on the amine.

Pure 2,4-difluoromesitylene is a colorless liquid, f. p. ca. –18.5°, b. p. 69.5° (20 mm.) or 168–169° (atm.),  $d_{20}^{20}$ , 1.183,  $n_D^{20}$  1.4682,  $\gamma_D^{20}$  30.94 dynes/cm.

*Anal.* Calcd. for  $C_8H_6F_2$ : C, 69.21; H, 6.46. Found: C, 69.36; H, 6.20.

**2,4-Difluoro-6-aminomesitylene (VI).**—Crude 2,4-difluoro-6-nitromesitylene (V) was reduced to the amine with iron filings as described previously. The crude amine was removed from the reaction mixture by steam distillation, yield 83%. Recrystallization from aqueous ethanol gave white, granular crystals, m. p. 51–51.5°.

*Anal.* Calcd. for  $C_8H_9NF_2$ : C, 63.13; H, 6.48. Found: C, 63.31; H, 6.28.

The acetyl derivative upon recrystallization from ethanol gave white needles, m. p. 185–186°.

*Anal.* Calcd. for  $C_{10}H_{11}ONF_2$ : C, 61.96; H, 6.14. Found: C, 62.21; H, 6.07.

**2,4,6-Trifluoromesitylene (VII).**—Approximately 349 g. (2.04 moles) of powdered crude difluoromesidine was digested in 635 cc. of hot concd. hydrochloric acid to form the amine hydrochloride, and then chilled rapidly to 0° with stirring. To the thick paste, a solution of 170 g. of sodium nitrite in 230 cc. of water was added slowly and the temperature not allowed to rise above 0°. The diazonium chloride solution with its precipitate of sodium chloride was cooled to –10°, and a solution of 560 g. of sodium fluoborate in 675 cc. of water was added. A heavy white magma of the diazonium fluoborate was obtained. The fluoborate salt was removed by filtration and dried in cool air (below 20°). A cool drying temperature was necessary as the damp salt had a tendency to liquefy at 25–30° until the moisture content had been reduced below a certain limit. Yield of dry salt was 533 g. or 97%; other experiments gave a yield range of 90–100%.

The fluoborate salt was decomposed thermally by low continuous heating in a large flask equipped with a reflux condenser. Air was passed through the condenser jacket but periodically some steam was used to melt down the solid condensate and thereby avoid condenser plugging. Vacuum distillation of the crude product gave a colorless main fraction, b. p. 91–94° (65 mm.), which solidified upon cooling. Purification may be effected also by sublimation. The yield data based on amine was (1) crude, 308 g., 86%; (2) distilled, 278 g. or 78%. Pure 2,4,6-trifluoromesitylene, m. p. 68°, b. p. 169°, is a white solid, quite volatile, sublimes slowly on standing to long, slender crystals, and it exhibits thixotropic properties in that the crystals appear to partially melt on mechanical working.

*Anal.* Calcd. for  $C_6H_3F_3$ : C, 62.03; H, 5.14. Found: C, 61.84; H, 5.16.

(11) Finger and Reed, *This Journal*, **66**, 1973 (1944).

(8) The authors are indebted to Mr. H. S. Clark, microanalyst of the Survey, for the analyses given in this investigation. Acknowledgment is made also of the assistance of Messrs. D. M. Burness, D. M. Fort, J. L. Finnerty and R. E. Oesterling.

(9) All melting and boiling points are uncorrected, and freezing points were determined with a toluene thermometer.

(10) Morgan and Davies, *J. Chem. Soc.*, 123, 231 (1923).



**Chlorination of 2,4,6-Trifluoromesitylene.**—The chlorination apparatus and procedure was similar to that described by McBee, *et al.*<sup>12</sup> No yield data were obtained due to the complexity of the reaction products and the difficulties encountered in isolating pure components.

Trifluoromesitylene was dissolved in a large excess of carbon tetrachloride and chlorinated below the boiling point of the solvent. The chlorination was strongly exothermic and rapid up to a "hexachloro" stage, whereupon it became very slow and the solvent was removed by distillation. This sluggish condition prevailed even at the higher temperatures (<200°). At the elevated temperatures, chlorinolysis of the methyl groups also took place since carbon tetrachloride in an appreciable amount and 2,4,6-trichloro-1,3,5-trifluorobenzene were found in the complex mixture of products. The yield of 2,4,6-tris-(trichloromethyl)-1,3,5-trifluorobenzene was rather low and it is quite conceivable that the chlorinolysis reaction was largely responsible for it. Fractional distillations and recrystallizations were used in isolating the various products.

The "hexachloro" compound was dissolved in petroleum ether and chromatographed through an aluminum oxide column with benzene as an eluant. A final recrystallization from ethanol gave white needles, m. p. 116–116.5°. It is quite likely that this compound is 2,4,6-tris-(dichloromethyl)-1,3,5-trifluorobenzene.

*Anal.* Calcd. for  $C_9H_3Cl_6F_3$ : C, 28.38; H, 0.79. Found: C, 28.49; H, 0.79.

2,4,6-Tris-(trichloromethyl)-1,3,5-trifluorobenzene upon recrystallization from ethanol gave white needles, m. p. 125–126°.

*Anal.* Calcd. for  $C_9Cl_9F_3$ : C, 22.32; Cl, 65.90. Found: C, 22.36; Cl, 66.03.

2,4,6-Trichloro-1,3,5-trifluorobenzene is a white solid, m. p. 62–63°, b. p. 79.5° (12 mm.).

*Anal.* Calcd. for  $C_6Cl_3F_3$ : C, 30.61. Found: C, 30.34, 30.45.

**Aceto Derivatives: Trifluoroacetomesitylene.**—Trifluoroacetic anhydride reacts with mesitylene in carbon disulfide with anhydrous aluminum chloride as a catalyst. A 16% yield of impure trifluoroacetomesitylene was obtained, b. p. 95–96.5° (25 mm.), and it was identified by nitration in red, fuming nitric acid to a dinitro derivative, m. p. 82.5° (ethanol).

*Anal.* Calcd. for  $C_{11}H_7F_3O_5N_2$ : C, 43.14; H, 2.96. Found: C, 43.26; H, 3.04.

**Acetodifluoromesitylene.**—Difluoromesitylene was converted to the aceto derivative by the usual Friedel-Crafts reaction with acetic anhydride, 85% yield. Pure acetodifluoromesitylene distills as a colorless product m. p. 23–24°, b. p. 120° (20 mm.) or 202–205° (atm.).

*Anal.* Calcd. for  $C_{11}H_7F_2O_2$ : C, 66.65; H, 6.10. Found: C, 66.65; H, 5.98.

**Tribromoacetodifluoromesitylene.**—The Hofmann hypomethine reaction<sup>13</sup> on acetodifluoromesitylene gave an 88% yield of the tribromoaceto derivative. Recrystallization from ethanol gave long, white needles of pure tribromoacetodifluoromesitylene, m. p. 81.5°.

*Anal.* Calcd. for  $C_{11}H_3Br_3F_2O$ : C, 30.38; H, 2.09. Found: C, 30.35; H, 2.10.

**Trichloroacetodifluoromesitylene.**—This compound was obtained in a 74% yield from acetodifluoromesitylene by the Hofmann hypochlorite reaction.<sup>13</sup> The pure compound is a heavy viscous oil, f. p. ca. –20.5°, b. p. 123° (5 mm.).

*Anal.* Calcd. for  $C_{11}H_3Cl_3F_2O$ : C, 43.81; H, 3.01. Found: C, 43.91; H, 2.95.

**eso-Difluoro- $\beta$ -isodurylic Acid.**—Ten grams of the tribromoacetodifluoromesitylene was hydrolyzed with difficulty to the  $\beta$ -isodurylic acid derivative by the Fuson and Walker<sup>13</sup> method. Recrystallization from benzene and sublimation gave the pure acid as white needles, m. p. 156–157°.

*Anal.* Calcd. for  $C_{10}H_{10}F_2O_2$ : C, 60.00; H, 5.04. Found: C, 60.25; H, 4.81.

**eso-Difluoro- $\beta$ -isodurylamide.**—A small sample of difluoromesidine was diazotized in hydrochloric acid and a Sandmeyer cuprous cyanide reaction gave the crude nitrile as a solid. The nitrile after recrystallization from ethanol and sublimation gave white needles, m. p. 67.5–68°, but an analysis indicated that it was slightly impure.

Hydrolysis of the impure nitrile by warming in concentrated sulfuric acid gave the isodurylamide derivative. Attempts to convert the amide to the acid failed even with a nitrosyl sulfuric acid mixture. Recrystallization from ethanol followed by sublimation gave the pure amide as a white powdery material, m. p. 196–197°.

*Anal.* Calcd. for  $C_{10}H_{11}F_2NO$ : C, 60.29; H, 5.57; N, 7.02. Found: C, 60.37; H, 5.61; N, 7.39.

#### Miscellaneous Derivatives

**4,6-Dinitro-2-fluoromesitylene.**—This compound was prepared by the nitration of fluoromesitylene or 4-nitro-2-fluoromesitylene in red, fuming nitric acid. Recrystallization from aqueous ethanol gave white needles, m. p. 95–96.5°.

*Anal.* Calcd. for  $C_9H_6O_4N_2F$ : C, 47.37; H, 3.97; N, 12.27. Found: C, 47.40; H, 3.96; N, 12.23.

**4-Amino-6-nitro-2-fluoromesitylene.**—A sodium polysulfide reduction on the preceding dinitro compound gave a quantitative yield of 4-amino-6-nitro-2-fluoromesitylene. An aqueous ethanol recrystallization gave yellow crystals, m. p. 72°. The acetyl derivative was obtained as almost colorless needles, m. p. 204.5–206°.

*Anal.* Calcd. for  $C_{10}H_8O_2N_2F$ : C, 54.99; H, 5.45; N, 11.66. Found: C, 54.88; H, 5.42; N, 11.69.

**4,6-Diamino-2-fluoromesitylene.**—Reduction of the preceding dinitro- or nitroaminofluoromesitylene gave the corresponding diamine. Recrystallization from high boiling petroleum ether gave long, white needles, m. p. 134–135°.

*Anal.* Calcd. for  $C_9H_{11}N_2F$ : C, 64.14; H, 7.78. Found: C, 64.50; H, 7.61.

**2-Chloro-4-fluoromesitylene.**—This compound was obtained in a very small amount as a by-product in the synthesis of 2,4-difluoromesitylene. It is a colorless liquid, f. p. –8°, b. p. 203–204°,  $n_D^{20}$  1.51046.

*Anal.* Calcd. for  $C_9H_7ClF$ : C, 62.61; H, 5.84. Found: C, 62.61; H, 5.82.

#### Summary

Nitration of mesitylene and difluoromesitylene in anhydrous hydrofluoric acid gave near quantitative yields of dinitromesitylene and 2,4-difluoro-6-nitromesitylene, respectively. Difluoro- and trifluoromesitylene were synthesized by the Schiemann reaction in record yields reported for this type of reaction. Various intermediates and derivatives are reported for the fluoromesitylenes.

Among the products of exhaustive chlorination of trifluoromesitylene, 2,4,6-tris-(trichloromethyl)-1,3,5-trifluorobenzene and 2,4,6-trichloro-1,3,5-trifluorobenzene were identified.

URBANA, ILL.

RECEIVED JUNE 9, 1950

(12) McBee, *et al.*, *Ind. Eng. Chem.*, **39**, 395 (1947).

(13) Fuson and Walker, *This Journal*, **62**, 3274 (1930).

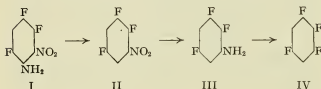
[CONTRIBUTION FROM THE GROCHEMICAL SECTION OF THE ILLINOIS STATE GEOLOGICAL SURVEY]

Aromatic Fluorine Compounds. IV. 1,2,3,5-Tetrafluorobenzene<sup>1</sup>

BY G. C. FINGER, F. H. REED AND R. E. OESTERLING

As a result of the availability of 3-nitro-4-amino-1,2,5-trifluorobenzene<sup>2</sup> in this Laboratory, the synthesis of 1,2,3,5-tetrafluorobenzene has been accomplished, and a study made of some of its properties and derivatives.

The first step in the synthesis involved the demethylation of 3-nitro-4-amino-1,2,5-trifluorobenzene (I) to 3-nitro-1,2,5-trifluorobenzene (II). Since I is a weakly basic amine, it was diazotized by



the nitrosylsulfuric phosphoric acid procedure.<sup>3,4</sup> Reduction of the diazonium salt by the usual hypophosphorous acid method<sup>5</sup> was unsuccessful until it was discovered that cuprous oxide catalyzed the reaction to give a 60-70% yield of 3-nitro-1,2,5-trifluorobenzene. The catalyst not only changed failure to success, but also effected the reduction in minutes rather than hours as is usually the case. The reductive power of the hypophosphorous acid-cuprous oxide combination was reflected also in the formation of some 3-amino-1,2,5-trifluorobenzene (III) as a secondary reduction product. This catalyst was used effectively in another instance which will appear in a later publication. In spite of the general application of cuprous oxide in ethanol demethylations, it is only recently that this catalyst had been used in the hypophosphorous acid method by Kornblum and co-workers.<sup>6</sup>

An iron reduction of II readily gave a 90% yield of 3-amino-1,2,5-trifluorobenzene (III), and a subsequent diazotization-Schiemann transformation gave a 40% yield of 1,2,3,5-tetrafluorobenzene (IV).

1,2,3,5-Tetrafluorobenzene in contrast to the 1,2,4,5-isomer<sup>2</sup> boils lower, 83° versus 87°, and can be converted readily to a nitro derivative, 4-nitro-1,2,3,5-tetrafluorobenzene. An iron reduction of the nitro compound gave 4-amino-1,2,3,5-tetrafluorobenzene.

(1) Presented before the Organic Division at the 117th Meeting of the American Chemical Society, Philadelphia, Pa., April, 1950. The authors wish to acknowledge the financial assistance of the Office of Naval Research provided by cooperative research contract N6ori-71; Task XIV. Published with the permission of the Chief of the Illinois State Geological Survey.

(2) Finger, Reed, Burgess, Fort and Blough, *THIS JOURNAL*, **73**, 145 (1951).

(3) Schoutissen, *ibid.*, **65**, 4531 (1933).

(4) C. Weygand, "Organic Preparations," Interscience Publishers, Inc., New York, N. Y., 1945, Ch. 2, p. 110.

(5) "Organic Reactions," John Wiley and Sons, Inc., New York, N. Y., 1944, Vol. II, Ch. 7, p. 277.

(6) Kornblum and Cooper, Abstracts of the 116th Meeting, American Chemical Society, Atlantic City, N. J., Sept. 1949, p. 50M.

Experimental<sup>7,8</sup>

**3-Nitro-1,2,5-trifluorobenzene (II).**—Approximately 96 g. of 3-nitro-4-amino-1,2,5-trifluorobenzene<sup>2</sup> was dissolved in 250 cc. of concd. sulfuric acid with stirring. The clear orange solution was allowed to stand 2-3 hours to come to room temperature. A prolonged time interval appears to be necessary to complete the formation of the amine hydro-sulfate, otherwise diazotization will be quite unsatisfactory. Nitrosylsulfuric acid solution was prepared by adding 40 g. of sodium nitrite to 200 g. of concd. sulfuric acid (precooled to 0°) with stirring, and then cooled to 20°. The amine salt was diazotized at 0° with vigorous stirring by adding the nitrosylsulfuric acid followed by the dropwise addition of 450 cc. of sirupy phosphoric acid (85%). Stirring was continued for thirty minutes at 0-10°.

To the diazonium solution, a slurry of 71 g. of cuprous oxide, 169 g. of sodium hypophosphite and 200 cc. of water was added at such a rate as to control the foaming due to nitrogen evolution. In order to minimize the formation of amine (III) from the nitro (II) compound by a secondary reaction, the exothermic reaction was kept below 50°. After completion of the reaction, within five minutes after the slurry had been added, the reaction mixture was diluted with an equal volume of water and immediately steam distilled. The crude nitro distillate, contaminated with amine, gave a yield of 55-61 g. or 62-67%. An ether extraction of the aqueous distillate increased the yield by 10-15%. Vacuum distillation gave pure 3-nitro-1,2,5-trifluorobenzene, f. p. ca. -20°, b. p. 187° (micro cap.),  $n_D^{20}$  1.4873.

*Anal.* Calcd. for  $C_6H_3F_3NO_2$ : C, 40.69; H, 1.14; N, 7.91. Found: C, 40.71; H, 1.38; N, 8.10.

**3-Amino-1,2,5-trifluorobenzene (III).**—This compound was prepared by the usual reduction with iron filings in ammonium chloride solution (0.78 N)<sup>9</sup> and the amine was removed by steam distillation. Vacuum distillation gave a yield of 95-100 g. or 89-92% of pure 3-amino-1,2,5-trifluorobenzene as a colorless liquid, b. p. 76° (20 mm.),  $n_D^{20}$  1.4899.

*Anal.* Calcd. for  $C_6H_4NF_3$ : C, 48.99; H, 2.74; N, 9.52. Found: C, 49.08; H, 2.49; N, 9.69.

The acetyl derivative was recrystallized from ether as white granular crystals, m. p. 120-121°.

*Anal.* Calcd. for  $C_8H_6ONF_3$ : N, 7.41. Found: N, 7.69.

**1,2,3,5-Tetrafluorobenzene (IV).**—To 20 cc. of concd. hydrochloric acid in 10 cc. of water, 14.7 g. of 3-amino-1,2,5-trifluorobenzene was added slowly with rapid stirring, and the amine hydrochloride was formed as a very insoluble salt.

In order to avoid undesirable side reactions and a low yield, diazotization and diazonium fluoborate precipitation were effected concurrently. To a solution of 20 cc. of concd. hydrochloric acid in 10 cc. of water, there were added, simultaneously but separately, three reactants, (1) the amine hydrochloride slurry, (2) 7.6 g. of sodium nitrite in 10 cc. of water, and (3) 40 g. of sodium fluoborate in 60 cc. of water. The additions required 30 minutes, and the reaction temperature was maintained at 0°. Stirring was continued for one hour at 0-10°. The diazonium fluoborate was removed by filtration at -10°, dried and a yield of 22 g. or 89% was obtained. Thermal decomposition of the salt and a subsequent steam distillation gave the crude tetrafluorobenzene, yield 6.5 g. or 43% based on the amine. 1,2,3,5-Tetrafluorobenzene is a colorless liquid with a faint sweet odor, f. p. ca. -48°, b. p. 83°,  $d_4^{20}$  1.393,  $n_D^{20}$  1.40381,  $\gamma_{20}^{20}$  23.99.

*Anal.* Calcd. for  $C_6H_2F_4$ : C, 48.01; H, 1.35; F, 50.64. Found: C, 48.21; H, 1.43; F, 50.43.

(7) Analyses by Mr. H. S. Clark, microanalyst for the Illinois Geological Survey.

(8) All melting and boiling points are uncorrected, and freezing points were determined with a toluene thermometer.

(9) Finger and Reed, *THIS JOURNAL*, **66**, 1972 (1944).

**3-Chloro-1,2,5-trifluorobenzene.**—This compound was obtained as a by-product from IV. It is a colorless liquid, b.p. 121° (micro cap.),  $n_D^{20}$  1.4550.

*Anal.* Calcd. for  $C_6H_3ClF_3$ : C, 43.27; H, 1.21. Found: C, 43.57; H, 1.24.

**4-Nitro-1,2,3,5-tetrafluorobenzene.**—To a mixture of 25 g. of 1,2,3,5-tetrafluorobenzene and 30 cc. of concd. sulfuric acid, a solution of 12 cc. of concd. nitric acid in 10 cc. of concd. sulfuric acid was added at 0–10°, followed by stirring, for two hours at 10°. The yield of crude steam distilled nitro compound was 23 g. or 72%. Vacuum distillation gave pure 4-nitro-1,2,3,5-tetrafluorobenzene, b.p. 78.5° (20 mm.),  $n_D^{20}$  1.46507, f.p. ca. –5°.

*Anal.* Calcd. for  $C_6H_3F_4NO_2$ : C, 36.94; H, 0.52; N, 7.18. Found: C, 37.17; H, 0.65; N, 7.24.

**4-Amino-1,2,3,5-tetrafluorobenzene.**—This amine was obtained from the preceding nitro compound by the usual

iron reduction<sup>9</sup> in an 86% crude yield. It is a steam distillable liquid, b.p. 65° (20 mm.),  $n_D^{20}$  1.46228.

*Anal.* Calcd. for  $C_6H_4NF_4$ : C, 43.65; H, 1.83; N, 8.49. Found: C, 43.65; H, 1.79; N, 8.35.

The acetyl derivative was obtained as white, granular crystals from ethanol, m.p. 140–141°.

*Anal.* Calcd. for  $C_8H_4ONF_4$ : N, 6.76. Found: N, 6.78.

### Summary

The preparation of 1,2,3,5-tetrafluorobenzene and some of its intermediates is described.

Cuprous oxide as a catalyst was used to advantage in the hypophosphorous acid deamination method.

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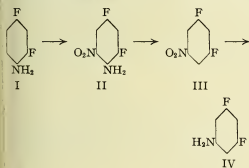
[CONTRIBUTION FROM THE GEOCHEMICAL SECTION OF THE ILLINOIS STATE GEOLOGICAL SURVEY]

## Aromatic Fluorine Compounds. V. 1,3,5-Trifluorobenzene<sup>1</sup>

By G. C. FINGER, F. H. REED AND J. L. FINNERTY

Among the polyfluorobenzenes there has been considerable speculation as to the probable physical and chemical properties of symmetrical trifluorobenzene. This compound has now been synthesized and some of its properties and derivatives have been studied.

The nitration of the acetyl derivative of 4-amino-1,3-difluorobenzene (I) gave 4-amino-5-nitro-1,3-difluorobenzene (II). Reduction of the nitroamine to the diamine, followed by the formation of 2,3-diphenyl-5,7-difluoroquinoxaline proved the adjacency of the nitro and amine groups. A modified hypophosphorous acid deamination procedure<sup>2</sup> gave an average yield of 50% of 5-nitro-1,3-difluorobenzene (III), and a subsequent iron reduction gave 5-amino-1,3-difluorobenzene (IV).



A diazotization-Schiemann transformation on the amine gave a 60% yield of 1,3,5-trifluorobenzene (V).

The boiling point of 1,3,5-trifluorobenzene is 55°, thus making it the only fluorinated benzene boiling lower than benzene, 80°. It is odorless, whereas its isomer 1,2,4-trifluorobenzene, and the next higher homolog, 1,2,4,5-tetrafluorobenzene have a faint, sweet odor.

Chlorination and bromination gave the mono, di and trihalo derivatives. The trichloro derivative was identical with 2,4,6-trichloro-1,3,5-trifluorobenzene obtained by the chlorinolysis of trifluoromesitylene.<sup>3</sup>

Symmetrical trifluorobenzene was readily nitrated to 2-nitro-1,3,5-trifluorobenzene, and an iron reduction gave the corresponding 2-amino-1,3,5-trifluorobenzene. The amine reacted readily with hydrochloric or sulfuric acids to form the amine salts. The hydrosulfate salt was surprisingly soluble.

Nitration of the acetyl derivative of IV gave 4-nitro-5-amino-1,3-difluorobenzene; the nitro group entered an ortho position to the amino rather than the expected para. The structure of the nitroamine was proven by deamination to the known 4-nitro-1,3-difluorobenzene.

### Experimental<sup>4,5</sup>

**4-Amino-5-nitro-1,3-difluorobenzene (II).**—In a mixture of 400 cc. of concd. sulfuric acid and 140 cc. of acetic acid, 340 g. of 4-acetylaminobenzene<sup>6,7</sup> was dissolved with stirring. After cooling to 20°, a mixture containing equal volumes (140 cc. each) of concd. nitric and sulfuric acids was added in fifteen minutes, and the temperature allowed to rise to 40°. Stirring was continued for 90 minutes at 40–50°. The reaction mixture was poured over ice, and the crude nitroacetylaminobenzene compound after drying weighed 400 g. The crude product was hydrolyzed to the nitroamine in 350 cc. of concd. sulfuric acid by heating for two hours on a steam-bath, and then poured over ice. The yield of dry crude product was 228 g. or 65%. The nitroamine is steam distillable, but the purest product was obtained by recrystallization from ethanol followed by sublimation. No tangible evidence was obtained for the existence of other nitroamine isomers. Pure 4-amino-5-nitro-1,3-difluorobenzene is a yellow solid, m.p. 85.5–86.5°.

*Anal.* Calcd. for  $C_6H_4O_2N_2F_2$ : C, 41.39; H, 2.31; N, 16.08. Found: C, 41.48; H, 2.14; N, 15.91.

The acetyl derivative was recrystallized as cream colored

(1) Presented before the Organic Division at the 117th Meeting of the American Chemical Society, Philadelphia, Pennsylvania, April 30. The authors wish to acknowledge the financial assistance of the office of Naval Research provided by cooperative research Contract 60-71; Task XIV. Published with the permission of the Chief of the Illinois State Geological Survey.

(2) Finger, Reed and Oesterling, *This Journal*, **73**, 152 (1951).

(3) Finger, Reed, Maynert and Weiner, *ibid.*, **73**, 149 (1951).

(4) Analyses, densities and surface tension measurements by H. S. Clark, microanalyst for the Illinois Geological Survey.

(5) Melting and boiling points are uncorrected, and the freezing points were determined with a toluene thermometer.

(6) Swarts, *Rec. trav. chim.*, **35**, 154 (1915).

(7) Schiemann, *J. prakt. Chem.*, **140**, 97 (1934).



needles from an ethanol-chloroform mixture, m.p. 142–143°.

Anal. Calcd. for  $C_8H_6O_2N_2F_2$ : N, 12.96. Found: N, 12.66.

**4,5-Diamino-1,3-difluorobenzene.**—Four grams of the preceding nitroamine (II) was reduced to the diamine by addition with stirring to 24 g. of stannous chloride in 30 cc. of concd. hydrochloric acid. The reaction mixture after being made alkaline with sodium hydroxide solution, was extracted with ether, and evaporation of the ether extract gave the crude diamine. Recrystallization from an *n*-pentane-ether mixture followed by sublimation gave the 4,5-diamino-1,3-difluorobenzene as white crystals, m.p. 48.5–49.5°.

One gram of the diamine was condensed with 1.4 g. of benzil in 70 cc. of water by heating and stirring for one hour. The insoluble crude product was purified by recrystallizations from ethanol and methanol and also sublimations to give pure 2,3-diphenyl-5,7-difluoroquinoxaline as a white solid, m.p. 137–138°.

Anal. Calcd. for  $C_{20}H_{12}N_2F_2$ : C, 75.46; H, 3.80; N, 8.80. Found: C, 75.56; H, 3.73; N, 8.87.

**5-Nitro-1,3-difluorobenzene (II).**—The 4-amino-5-nitro-1,3-difluorobenzene was diazotized by the nitrosylsulfuric-phosphoric acid procedure<sup>8,9</sup> for weakly basic amines. The final deamination step with hypophosphorous acid<sup>10</sup> was successful only when cuprous oxide was used as a catalyst.

A solution of 67 g. of pure 4-amino-5-nitro-1,3-difluorobenzene (II) in 150 cc. of concd. sulfuric acid was stirred for three hours to form the amine salt. Nitrosylsulfuric acid was prepared by dissolving 28 g. of sodium nitrite in 150 cc. of concd. sulfuric acid (precooled to 0°) with stirring, and the mixture cooled to 20°. To the amine hydrosulfate at 0°, the nitrosylsulfuric acid was added and the reaction temperature allowed to rise to 10°. In order to complete the diazotization, 300 cc. of 85% phosphoric acid was added slowly in two hours while the temperature was maintained at 10–15°.

To the rapidly stirred diazonium solution at 0°, a slurry of 250 g. of sodium hypophosphite, 35 g. of cuprous oxide and 150 cc. of water was added slowly and the exothermic reaction kept below 35°. Nitrogen evolution was practically complete after 80% of the slurry had been added. The reaction mixture, after dilution with an equal volume of water and transference to a large flask (12-l.) was cautiously steam distilled. A large flask is essential as the hypophosphorous acid, near the end of the steam distillation, reduces the copper salts by an almost uncontrollable exothermic reaction causing the entire mixture to superheat and foam suddenly. The yield of pure 5-nitro-1,3-difluorobenzene was 37 g. or 60%, f.p. ca. 17.5°, b.p. 78–79° (20 mm.) or 176–177° (atm.).

Anal. Calcd. for  $C_6H_3O_2NF_2$ : C, 45.30; H, 1.90; N, 8.80. Found: C, 45.50; H, 1.70; N, 8.92.

**5-Amino-1,3-difluorobenzene (IV).**—To a stirred, refluxing mixture of 140 g. of iron filings in 200 cc. of ammonium chloride solution (0.78 *N*), 100 g. of 5-nitro-1,3-difluorobenzene was added slowly. The reduction was complete in two hours. Removal of the amine by steam distillation gave a yield of 75 g. or 92%. Vacuum distillation gave the pure amine as a white solid, m.p. 39–40°, b.p. 81–82° (20 mm.).

Anal. Calcd. for  $C_6H_7NF_2$ : C, 55.82; H, 3.90; N, 10.84. Found: C, 55.89; H, 4.03; N, 11.11.

The acetyl derivative was obtained as a white solid by successive recrystallizations from ethanol and benzene followed by sublimation, m.p. 129–129.5°.

Anal. Calcd. for  $C_8H_9ONF_2$ : C, 56.14; H, 4.13; N, 8.18. Found: C, 55.93; H, 4.09; N, 8.40.

**4-Nitro-5-amino-1,3-difluorobenzene.**—To a solution of 7 g. of the acetyl derivative of IV in 20 cc. of concd. sulfuric and 10 cc. of acetic acids, a mixture of concd. nitric-sulfuric acids (3.5 cc. of each acid) was added, and the reaction temperature maintained at 30–40°. Stirring was continued for 90 minutes after addition. After isolation of the

crude reaction product, it was hydrolyzed to the nitroamine by warming with 10 cc. of concd. sulfuric acid. Recrystallization from ethanol and *m*-fluorobenzotrifluoride,<sup>11</sup> and a final sublimation gave pure 4-nitro-5-amino-1,3-difluorobenzene as orange crystals, m.p. 107–108°. No evidence was found for the formation of other isomers, although this compound is isomeric with II.

Anal. Calcd. for  $C_6H_4N_2O_2F_2$ : C, 41.39; H, 2.31; N, 16.08. Found: C, 41.46; H, 2.12; N, 16.17.

Recrystallization of the acetyl derivative from *m*-fluorobenzotrifluoride gave white needles, m.p. 137–138°.

The structure of the nitroamine was established by deamination to 4-nitro-1,3-difluorobenzene<sup>6</sup> using the special procedure applied to II.

**1,3,5-Trifluorobenzene (V).**—To 200 cc. of concd. hydrochloric acid with rapid stirring, 75 g. of melted 5-amino-1,3-difluorobenzene was added slowly, and the amine hydrochloride paste was diluted with 80 cc. of water. Diazotization was effected at 0° by the addition of 42 g. of sodium nitrite as a 40% solution. To the clear diazonium solution, 160 g. of sodium fluoborate was added as a 40% solution, and the white diazonium fluoborate precipitate was filtered at –10°. The yield of dried fluoborate salt was 132 g. or 98%. The salt was thermally decomposed<sup>12</sup> by continuous heating, and steam distillation of the crude product gave a yield of 44 g. or 62.8% of trifluorobenzene based on the amine. A further treatment with cold concd. sulfuric acid followed by distillation through a packed 5-ft. vacuum-jacketed column gave pure 1,3,5-trifluorobenzene as a colorless, odorless liquid, f.p. ca. –5.5°, b.p. 75.5°,  $d_{20}^{25}$  1.277,  $n_D^{20}$  1.41403,  $\gamma^{25}$  27.16 dynes/cm.

Anal. Calcd. for  $C_6H_3F_3$ : C, 54.56; H, 2.29; F, 43.15. Found: C, 54.59; H, 2.19; F, 42.90.

**1-Chloro-3,5-difluorobenzene.**—This compound was obtained as a by-product from the synthesis of V. The pure compound is a colorless liquid, b.p. 118.5°,  $n_D^{20}$  1.4683.

Anal. Calcd. for  $C_6H_3ClF_2$ : C, 48.51; H, 2.03. Found: C, 48.59; H, 2.16.

**Chlorination of 1,3,5-Trifluorobenzene.**—A sample of 1,3,5-trifluorobenzene was chlorinated for six hours by bubbling chlorine through it in the presence of an iron catalyst. The chief product was 2-chloro-1,3,5-trifluorobenzene, f.p. ca. –2 to –3°, b.p. 124°,  $d_{20}^{25}$  1.463,  $n_D^{20}$  1.45505,  $\gamma^{25}$  28.59 dynes/cm.

Anal. Calcd. for  $C_6H_2ClF_3$ : C, 43.27; H, 1.21. Found: C, 43.52; H, 1.26.

Chlorination by the sulfuryl chloride-sulfur monochloride method<sup>14</sup> in the presence of aluminum chloride gave chiefly the dichloro compound along with a small amount of the trichloro derivative. The reaction product was steam distilled, and purified by fractional distillation. Pure 2,4-dichloro-1,3,5-trifluorobenzene is a colorless liquid, f.p. ca. –10 to –11°, b.p. 161.5–162°,  $d_{20}^{25}$  1.599,  $n_D^{20}$  1.48637,  $\gamma^{25}$  30.41 dynes/cm.

Anal. Calcd. for  $C_6HCl_2F_3$ : C, 35.85; H, 0.50; F, 28.36. Found: C, 35.91; H, 0.70; F, 28.41.

The trichloro derivative was isolated as a white solid by freezing the preceding high boiling fraction. Vacuum sublimation gave pure 2,4,6-trichloro-1,3,5-trifluorobenzene, m.p. 60–62°. A mixed melting point with a pure sample (m.p. 62–63°) obtained by the chlorinolysis of trifluoromethylene<sup>15</sup> showed no depression.

**Bromination of 1,3,5-Trifluorobenzene.**—Liquid bromine was added dropwise to 1,3,5-trifluorobenzene in the presence of iron with stirring at room temperature. A molar ratio of reactants gave the monobromo compound as the chief product and a small amount of the dibromo derivative. After steam distillation, the reaction mixture was fractionally distilled. 2-Bromo-1,3,5-trifluorobenzene is a colorless liquid with an unpleasant odor, f.p. ca. 3.5°, b.p. 140.5°,  $n_D^{20}$  1.48385.

Anal. Calcd. for  $C_6H_2BrF_3$ : C, 34.15; H, 0.96. Found: C, 34.16; H, 0.96.

2,4-Dibromo-1,3,5-trifluorobenzene was obtained from the higher boiling fraction in the preceding experiment.

(11) This compound has been found to be an excellent recrystallization solvent for many polyfluoronitroamines and their derivatives.

(12) Finger and Reed, *This Journal*, **66**, 1972 (1944).

(13) Cutter and Brown, *J. Chem. Ed.*, **21**, 443 (1944).

(8) Schoutissen, *This Journal*, **55**, 4531 (1933).

(9) C. Weygand, "Organic Preparations," Interscience Publishers, Inc., New York, N. Y., 1945, Ch. 2, p. 110.

(10) "Organic Reactions," John Wiley and Sons, Inc., New York, N. Y., 1944, Ch. 7, p. 277.

The data on the pure compound are m.p. 28–29°, b.p. 196–198°.

*Anal.* Calcd. for  $C_6HBr_3F_3$ : C, 24.86; H, 0.35; F, 19.66. Found: C, 25.02; H, 0.40, F, 19.44.

A large excess of bromine along with heating converted the monobromo compound to the tribromo derivative. Alternate vacuum sublimation and recrystallization from ethanol gave pure 2,4,6-tribromo-1,3,5-trifluorobenzene, m.p. 98–98.5°.

*Anal.* Calcd. for  $C_6Br_3F_3$ : C, 19.54. Found: C, 19.55.

**2-Nitro-1,3,5-trifluorobenzene.**—To a well-stirred mixture of 36 g. of 1,3,5-trifluorobenzene in 50 cc. of concd. sulfuric acid, a nitrating solution of 19 cc. of concd. nitric and 17 cc. of concd. sulfuric acids was added at such a rate that the temperature was controlled at 50°. At the end, the temperature was raised to 70° for sixty minutes. The reaction mixture was poured over ice, and the yield of crude nitro compound was 41 g. or 85%. Pure 2-nitro-1,3,5-trifluorobenzene is a heavy, pale yellow liquid, f.p. ca. 3.5°, b.p. 81° (20 mm.) or 172° (atm.),  $n_D^{20}$  1.47833.

*Anal.* Calcd. for  $C_6H_2O_2NF_3$ : C, 40.69; H, 1.14; N, 7.91. Found: C, 40.76; H, 1.16; N, 8.17.

**2-Amino-1,3,5-trifluorobenzene.**—This amine was prepared from the preceding nitro compound by the same general method as indicated for IV. A 90% yield of crude amine was obtained. Vacuum distillation gave pure 2-amino-1,3,5-trifluorobenzene as a white solid, m.p. 33–34°, b.p. 57° (22 mm.).

*Anal.* Calcd. for  $C_6H_4NF_3$ : C, 48.99; H, 2.74; N, 9.52. Found: C, 48.99; H, 2.69; N, 9.58.

The amine forms a very soluble hydrochloride and hydrosulfate in contrast to most other fluorinated anilines.

The acetyl derivative was sublimed after preliminary recrystallizations from ethanol and benzene, m.p. 152–153°.

*Anal.* Calcd. for  $C_8H_6ONF_3$ : C, 50.80; H, 3.20; N, 7.41. Found: C, 50.70; H, 3.11; N, 7.58.

### Summary

The synthesis and properties of 1,3,5-trifluorobenzene, its intermediates and some of its derivatives have been described.

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